APPENDIX 7. USEFUL INFORMATION

U.S. STANDARD ATMOSPHERE (1962)

Geopotential Altitude h (ft)	°F	Temp. T (°R)	°C	Temp. Ratio θ	Press. p (psi)	Press. Ratio δ	Density ρ (slug/ft³)	Density Ratio σ	Speed of Sound V_a (ft/sec)
0	59.0	518.7	15.0	1.000	14.70	1.000	2.3768×10^{-3}	1.000	1116.4
1000	55.4	515.1	13.0	.9932	14.17	.9644	2.3081	.97106	1112.6
2000	51.9	511.5	11.0	.9863	13.66	.9298	2.2409	.94277	1108.7
3000	48.3	508.0	9.1	.9794	13.17	.8962	2.1751	.91512	1104.9
4000	44.7	504.4	7.1	.9725	12.69	.8637	2.1109	.88809	1101.0
5000	41.2	500.8	5.1	.9657	12.23	.8320	2.0481	.86167	1097.1
6000	37.6	497.3	3.1	.9588	11.78	.8014	1.9868	.83586	1093.2
7000	34.0	493.7	1.1	.9519	11.34	.7716	1.9268	.81064	1089.2
8000	30.5	490.1	-0.9	.9450	10.92	.7428	1.8683	.78602	1085.3
9000	26.9	486.6	-2.8	.9382	10.50	.7148	1.8111	.76196	1081.4
10000	23.3	483.0	-4.8	.9313	10.11	.6877	1.7553	.73848	1077.4
11000	19.8	479.4	-6.8	.9244	9.720	.6614	1.7008	.71555	1073.4
12000	16.2	475.9	-8.8	.9175	9.346	.6360	1.6476	.69317	1069.4
13000	12.6	472.3	-10.8	.9107	8.984	.6113	1.5957	.67133	1065.4
14000	9.1	468.7	-12.7	.9038	8.633	.5875	1.5451	.65003	1061.4
15000	5.5	465.2	-14.7	.8969	8.294	.5643	1.4956	.62924	1057.3
16000	1.9	461.6	-16.7	.8900	7.965	.5420	1.4474	.60896	1053.2
17000	-1.6	458.0	-18.7	.8831	7.647	.5203	1.4004	.58919	1049.2
18000	-5.2	454.5	-20.7	.8763	7.339	.4994	1.3546	.56991	1045.1
19000	-8.8	450.9	-22.6	.8694	7.041	.4791	1.3100	.55112	1041.0
20000	-12.3	447.3	-24.6	.8625	6.754	.4595	1.2664	.53281	1036.8
21000	-15.9	443.8	-26.6	.8556	6.475	.4406	1.2240	.51497	1032.7
22000	-19.5	440.2	-28.6	.8488	6.207	.4223	1.1827	.49758	1028.5
23000	-23.0	436.6	-30.6	.8419	5.947	.4046	1.1425	.48065	1024.4
24000	-26.6	433.1	-32.5	.8350	5.696	.3876	1.1033	.46417	1020.2
25000	-30.2	429.5	-34.5	.8281	5.454	.3711	1.0651	.44812	1016.0

Figure 1

U.S. STANDARD ATMOSPHERE (1962)

Geopotential Altitude h ft	Temp. T °F	°R	°C	Temp. Ratio θ	Press. p psi	Press. Ratio δ	Density ρ slug/ft³	Density Ratio σ	Speed of Sound V_a ft/sec
26000	-33.7	426.0	-36.6	.8213	5.220	.3552	1.0280	.43250	1011.7
27000	-37.3	422.4	-38.5	.8144	4.994	.3398	.9919	.41730	1007.5
28000	-40.9	418.8	-40.5	.8075	4.777	.3250	.9567	.40251	1003.2
29000	-44.4	415.3	-42.5	.8006	4.567	.3107	.9225	.38812	999.0
30000	-48.0	411.7	-44.4	.7938	4.364	.2970	.8893	.37413	994.7
31000	-51.6	408.1	-46.4	.7869	4.169	.2837	.8569	.36053	990.3
32000	-55.1	404.6	-48.4	.7800	3.981	.2709	.8255	.34731	986.0
33000	-58.7	401.0	-50.4	.7731	3.800	.2586	.7950	.33447	981.6
34000	-62.2	397.4	-52.4	.7663	3.626	.2467	.7653	.32199	977.3
35000	-65.8	393.9	-54.3	.7594	3.458	.2353	.7365	.30987	972.9
36000	-69.4	390.3	-56.4	.7525	3.297	.2243	.7086	.29811	968.5
37000	-69.7	390.0	-56.5	.7519	3.142	.2138	.6759	.28435	968.1
38000	-69.7	390.0	-56.5	.7519	2.994	.2038	.6442	.27101	968.1
39000	-69.7	390.0	-56.5	.7519	2.854	.1942	.6139	.25829	968.1
40000	-69.7	390.0	-56.5	.7519	2.720	.1851	.5851	.24617	968.1
41000	-69.7	390.0	-56.5	.7519	2.592	.1764	.5577	.23462	968.1
42000	-69.7	390.0	-56.5	.7519	2.471	.1681	.5315	.22361	968.1
43000	-69.7	390.0	-56.5	.7519	2.355	.1602	.5065	.21311	968.1
44000	-69.7	390.0	-56.5	.7519	2.244	.1527	.4828	.20311	968.1
45000	-69.7	390.0	-56.5	.7519	2.139	.1455	.4601	.19358	968.1
46000	-69.7	390.0	-56.5	.7519	2.039	.1387	.4385	.18450	968.1
47000	-69.7	390.0	-56.5	.7519	1.943	.1322	.4180	.17584	968.1
48000	-69.7	390.0	-56.5	.7519	1.852	.1260	.3983	.16759	968.1
49000	-69.7	390.0	-56.5	.7519	1.765	.1201	.3796	.15972	968.1
50000	-69.7	390.0	-56.5	.7519	1.682	.1145	.3618	.15223	968.1

^{o}Rankine = ^{o}F + 459.7^{o}
^{o}Kelvin = ^{o}C + 273.2^{o}

Figure 1 (continued)

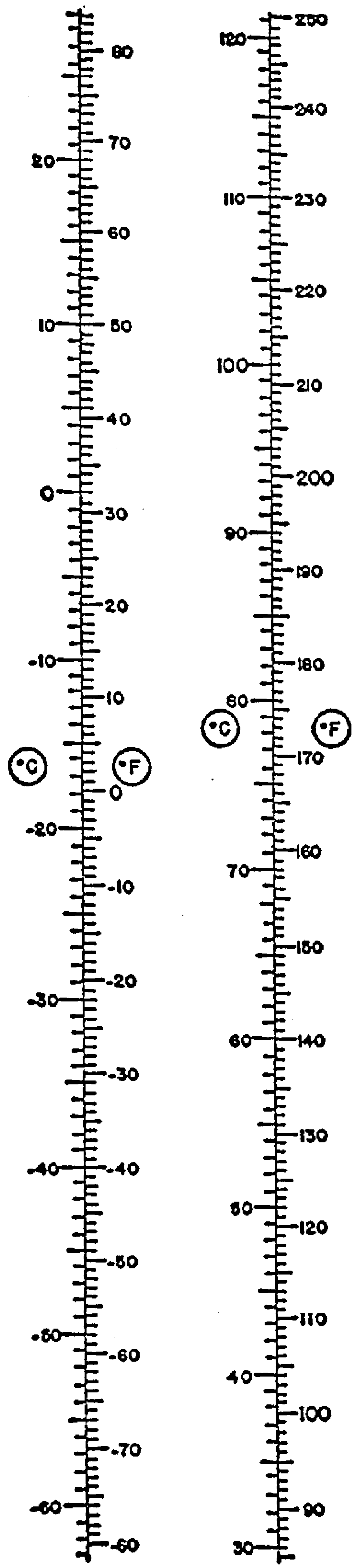

Figure 2 - TEMPERATURE CONVERSION CHART

DETERMINATION OF AIR TEMPERATURE IN RELATION TO INTERNATIONAL STANDARD ATMOSPHERE

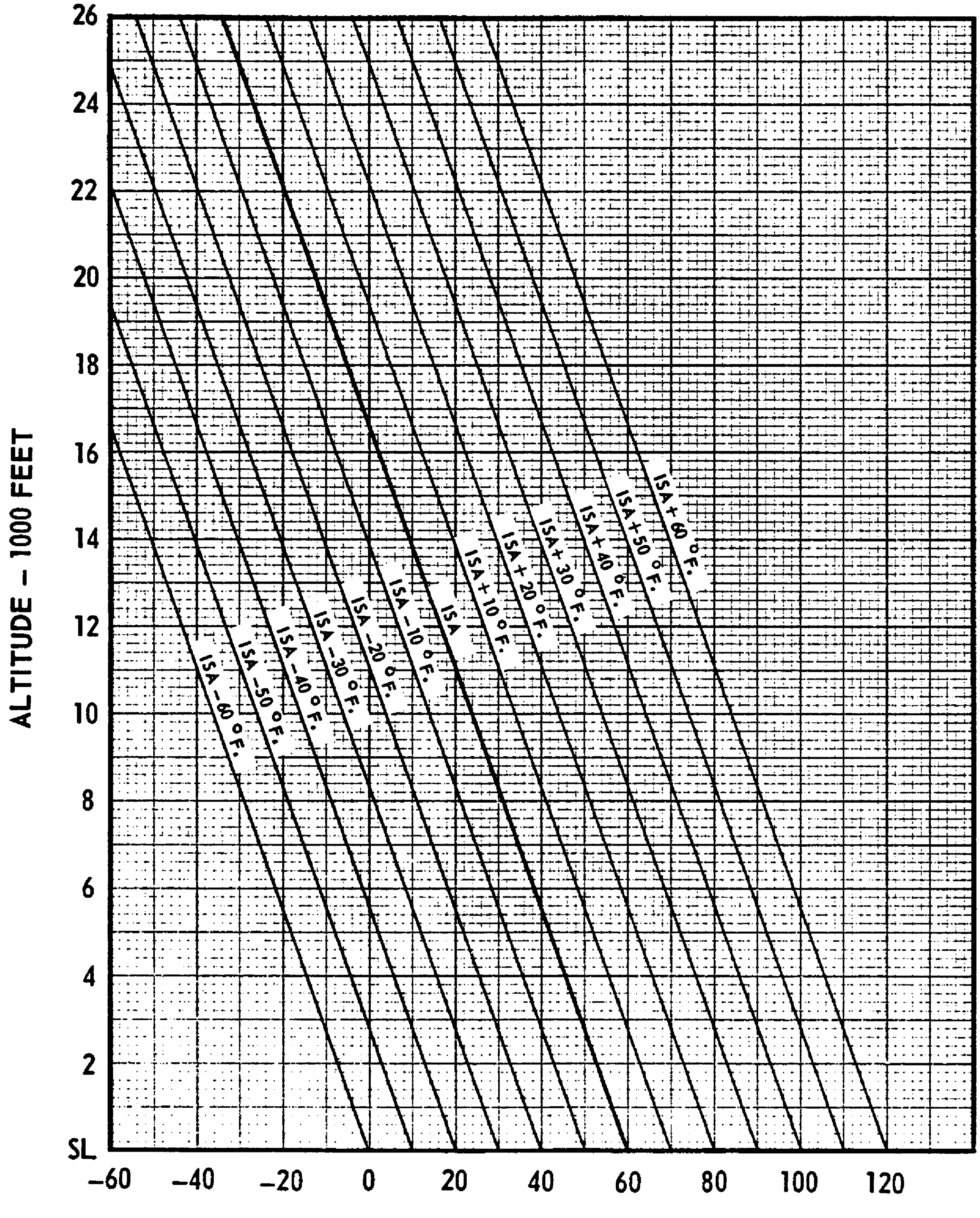

Figure 3

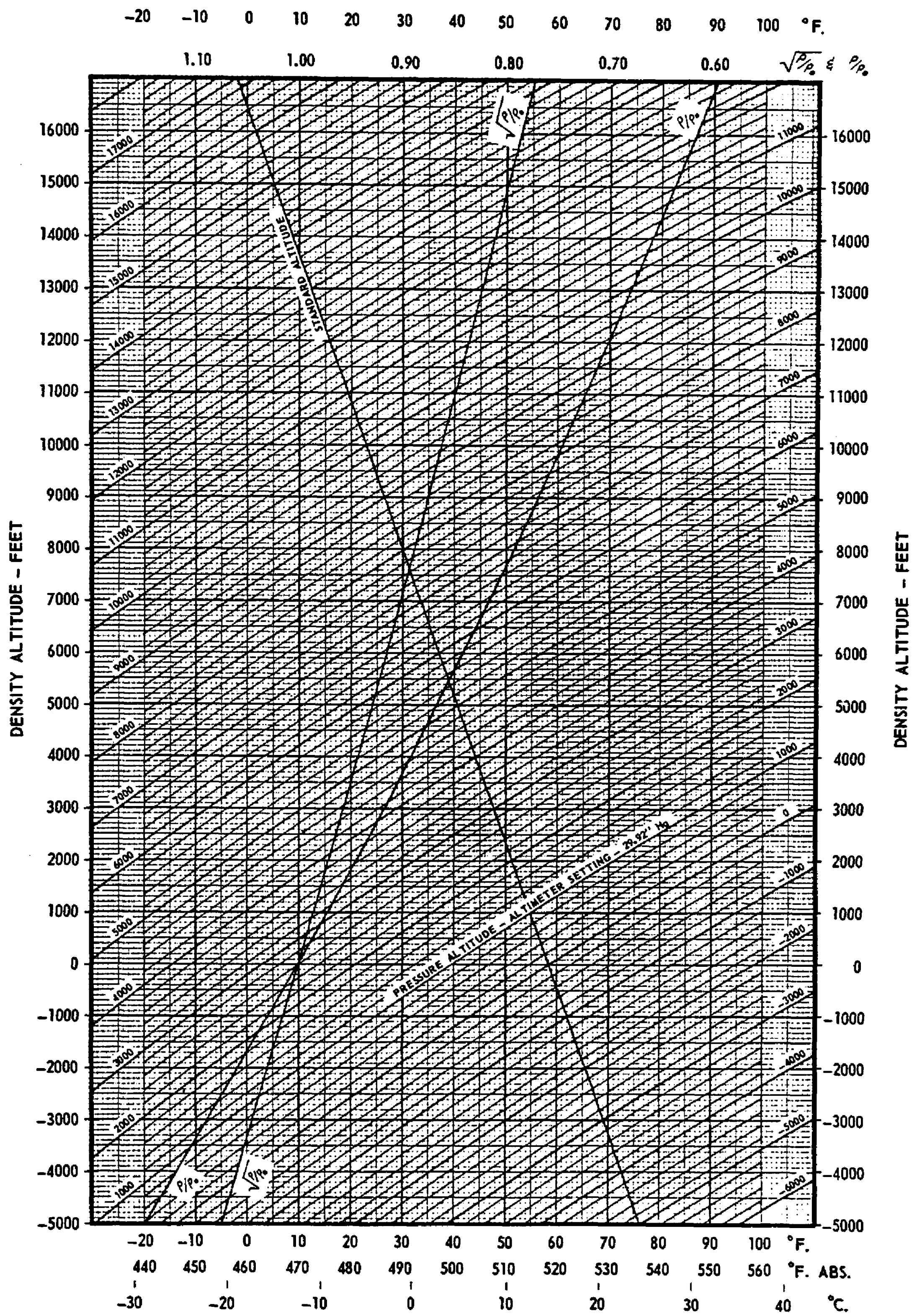

Figure 4 - DENSITY/PRESSURE ALTITUDE CONVERSION

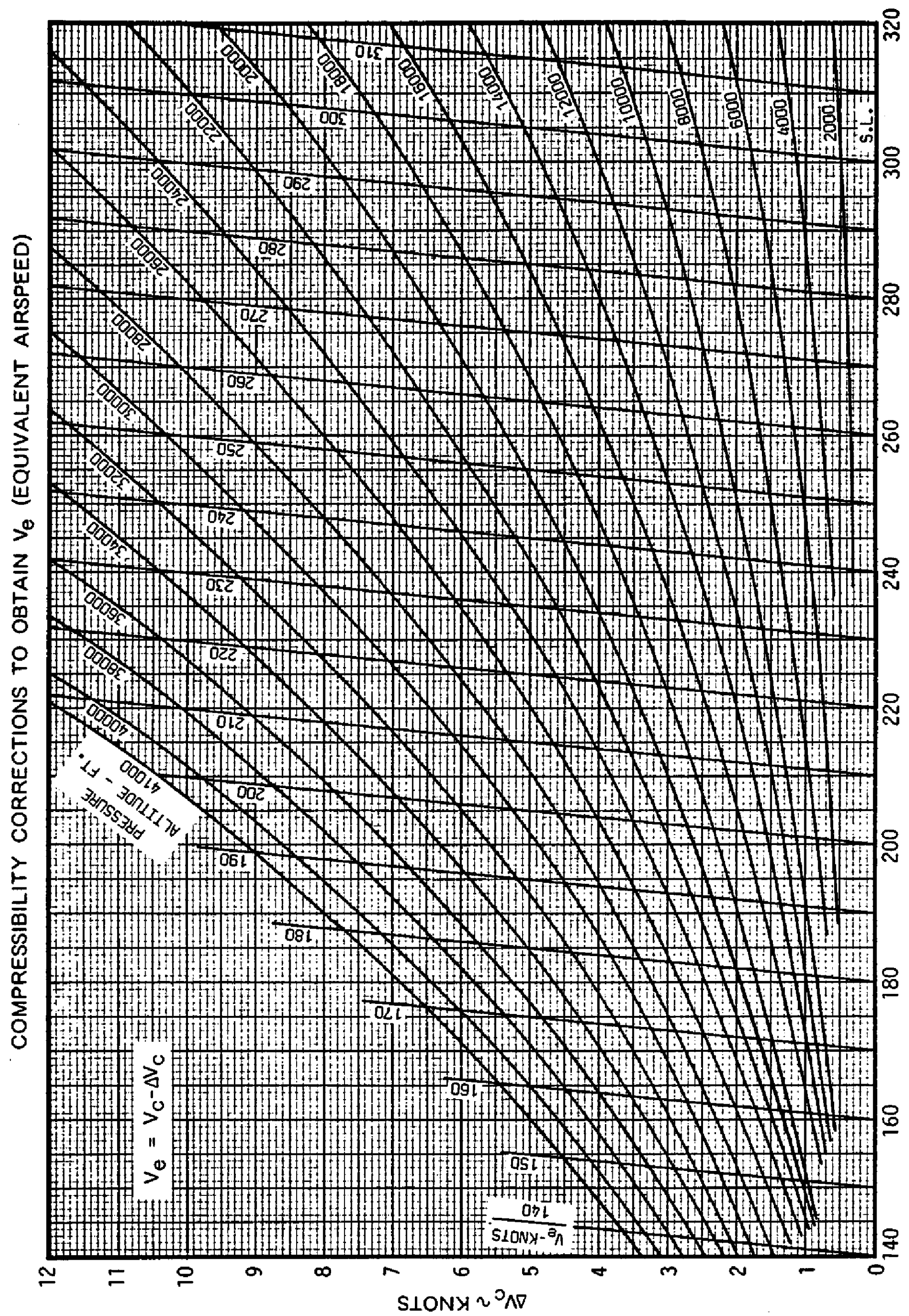

Figure 5 - COMPRESSIBILITY CORRECTION TO CAS

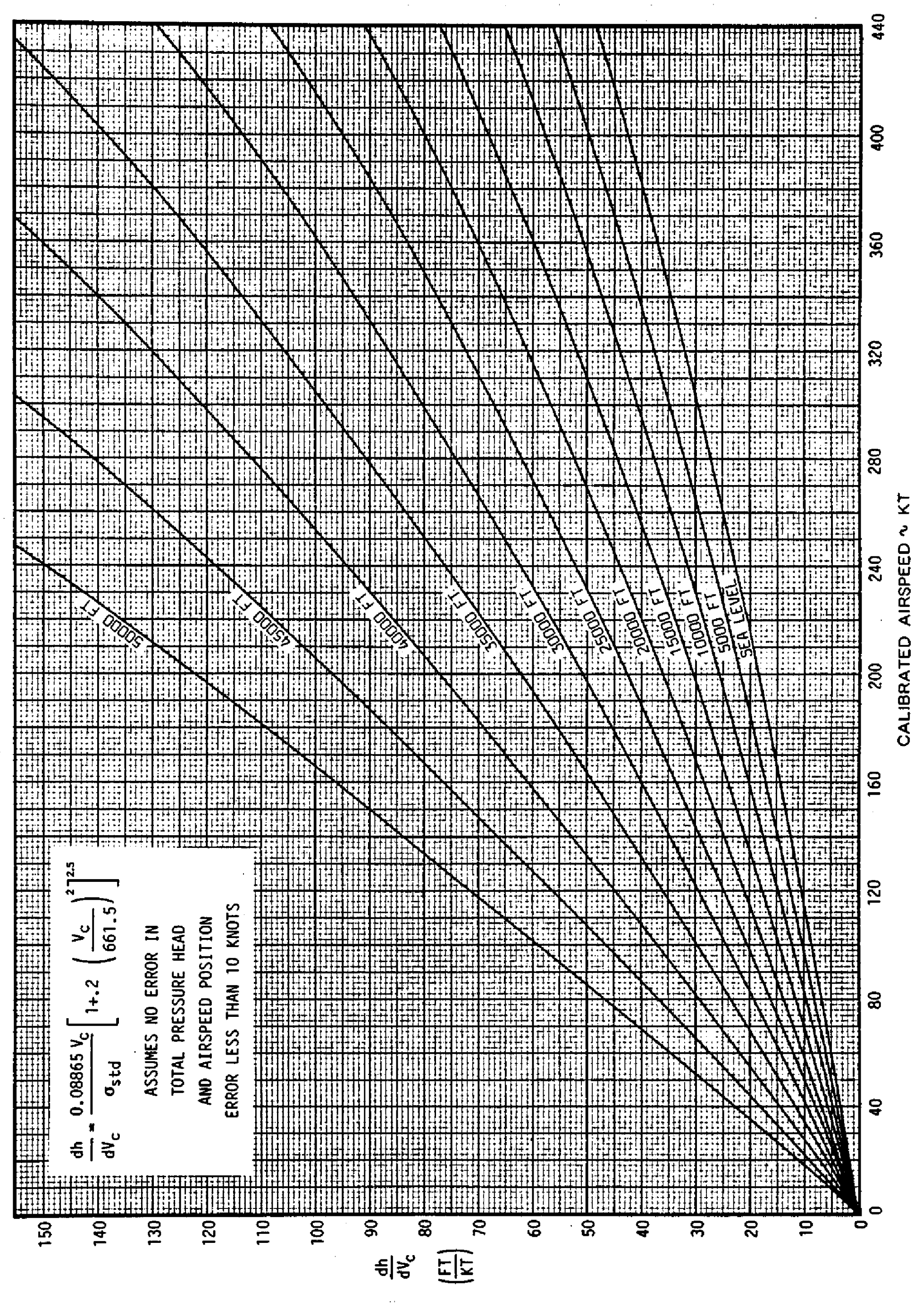

Figure 6 - ALTIMETER ERROR VS. CAS

$$\frac{\text{Indicated Temp. } (^{o}\text{K})}{\text{Outside Air Temp. } (^{o}\text{K})} = 1 + (\text{recovery factor}) \quad \frac{\text{mach number}^2}{5}$$

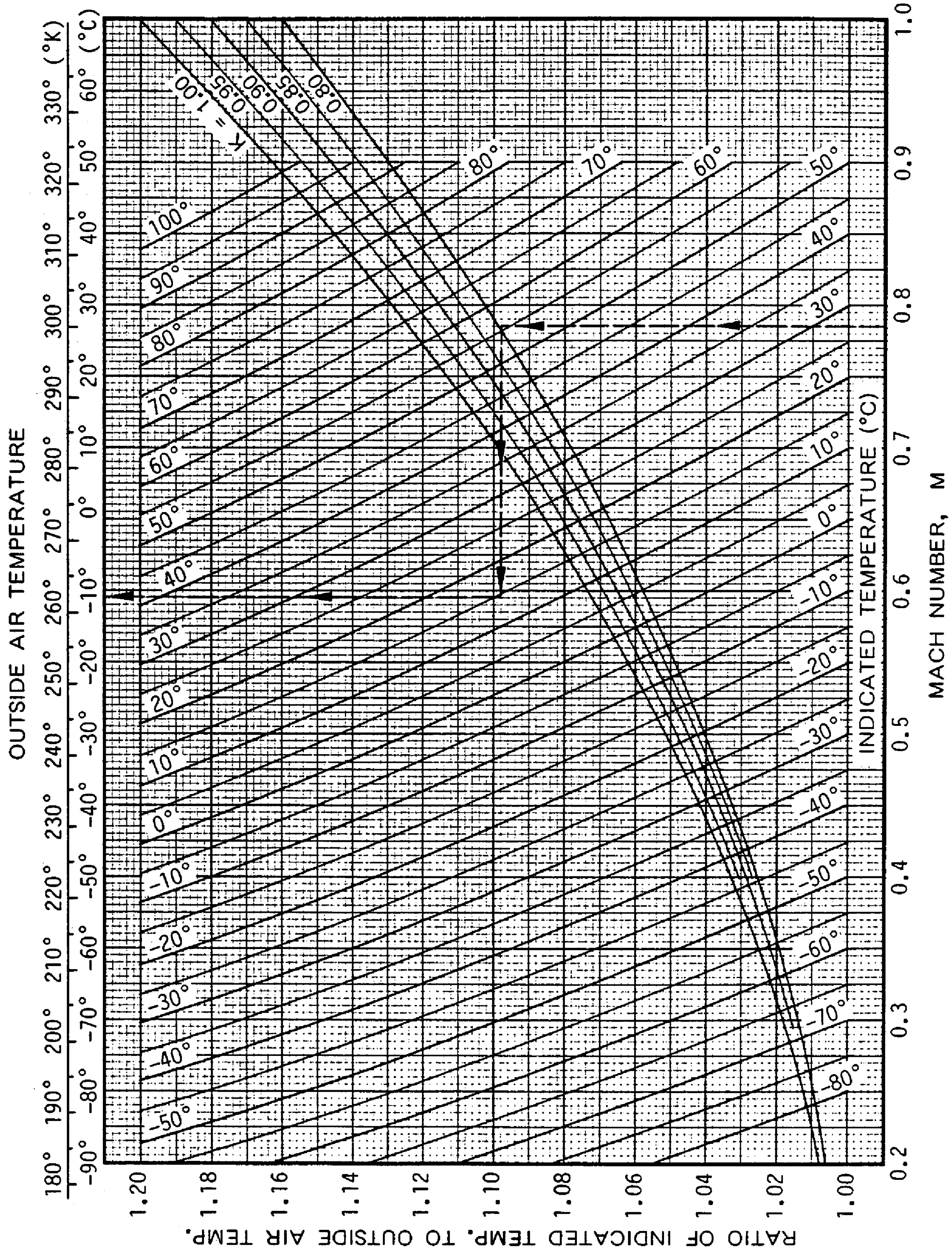

Figure 7 - TEMPERATURE RAM RISE

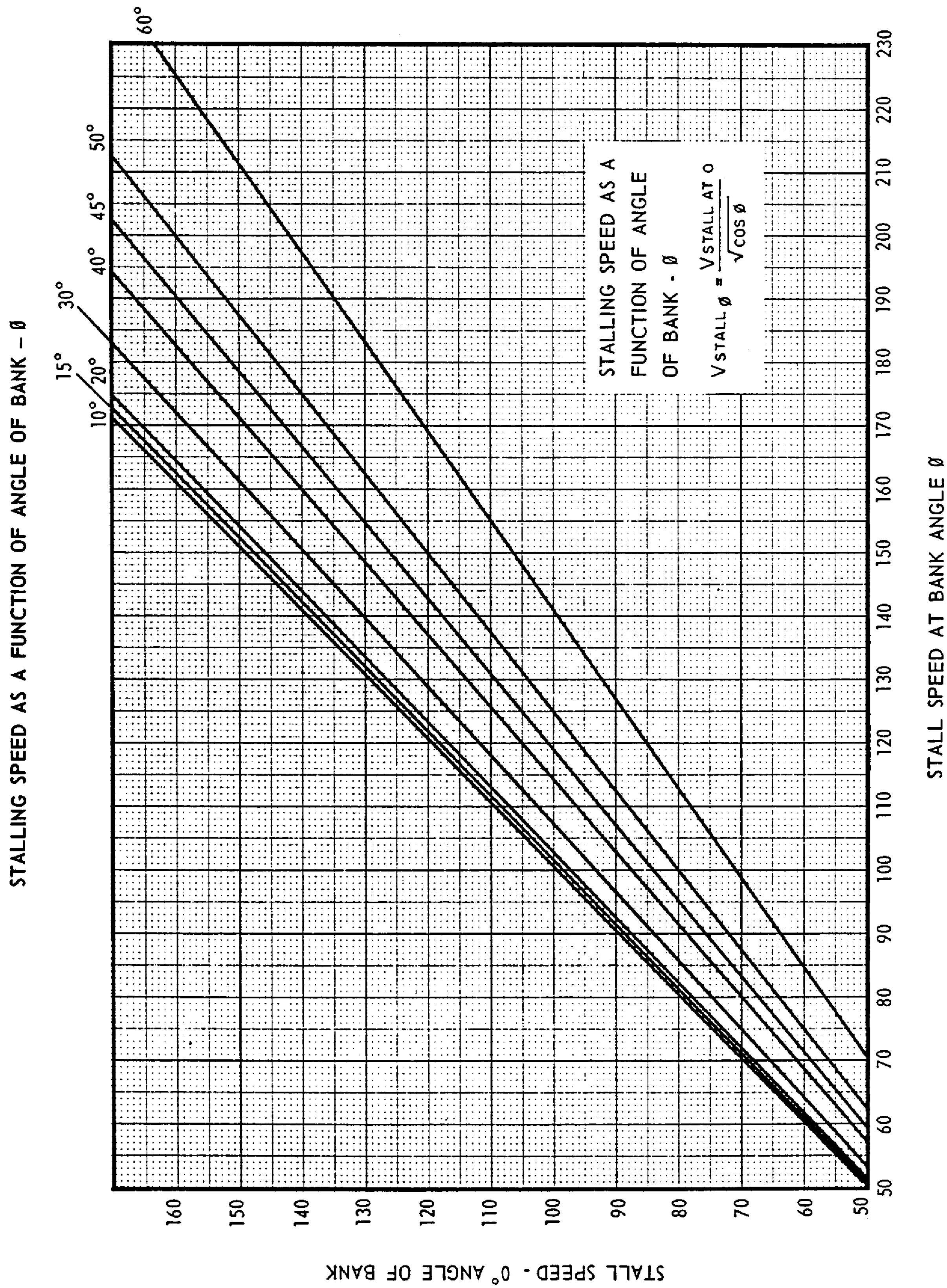
STALLING SPEED AS A FUNCTION OF ANGLE OF BANK - Ø
STALLING SPEED AS A FUNCTION OF ANGLE OF BANK - Ø
$V_{STALL\,Ø} = \frac{V_{STALL\ AT\ 0}}{\sqrt{\cos Ø}}$
10°
15°
20°
30°
40°
45°
50°
60°
STALL SPEED AT BANK ANGLE Ø
50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230
STALL SPEED - 0° ANGLE OF BANK
50 60 70 80 90 100 110 120 130 140 150 160

Figure 8

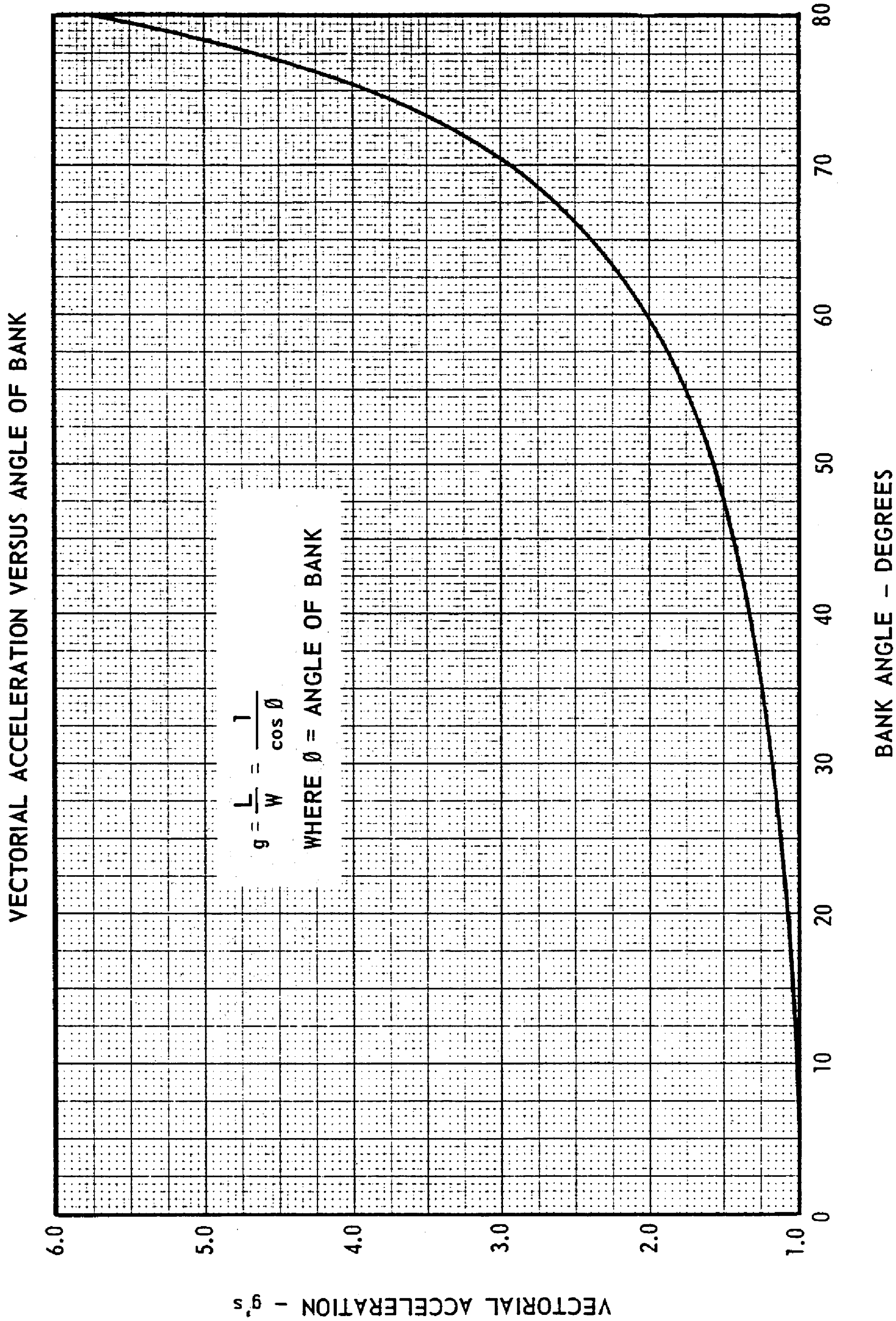
VECTORIAL ACCELERATION VERSUS ANGLE OF BANK
g = L/W = 1/cos Ø
WHERE Ø = ANGLE OF BANK
BANK ANGLE - DEGREES
0
10
20
30
40
50
60
70
80
VECTORIAL ACCELERATION - g's
1.0
2.0
3.0
4.0
5.0
6.0

Figure 9

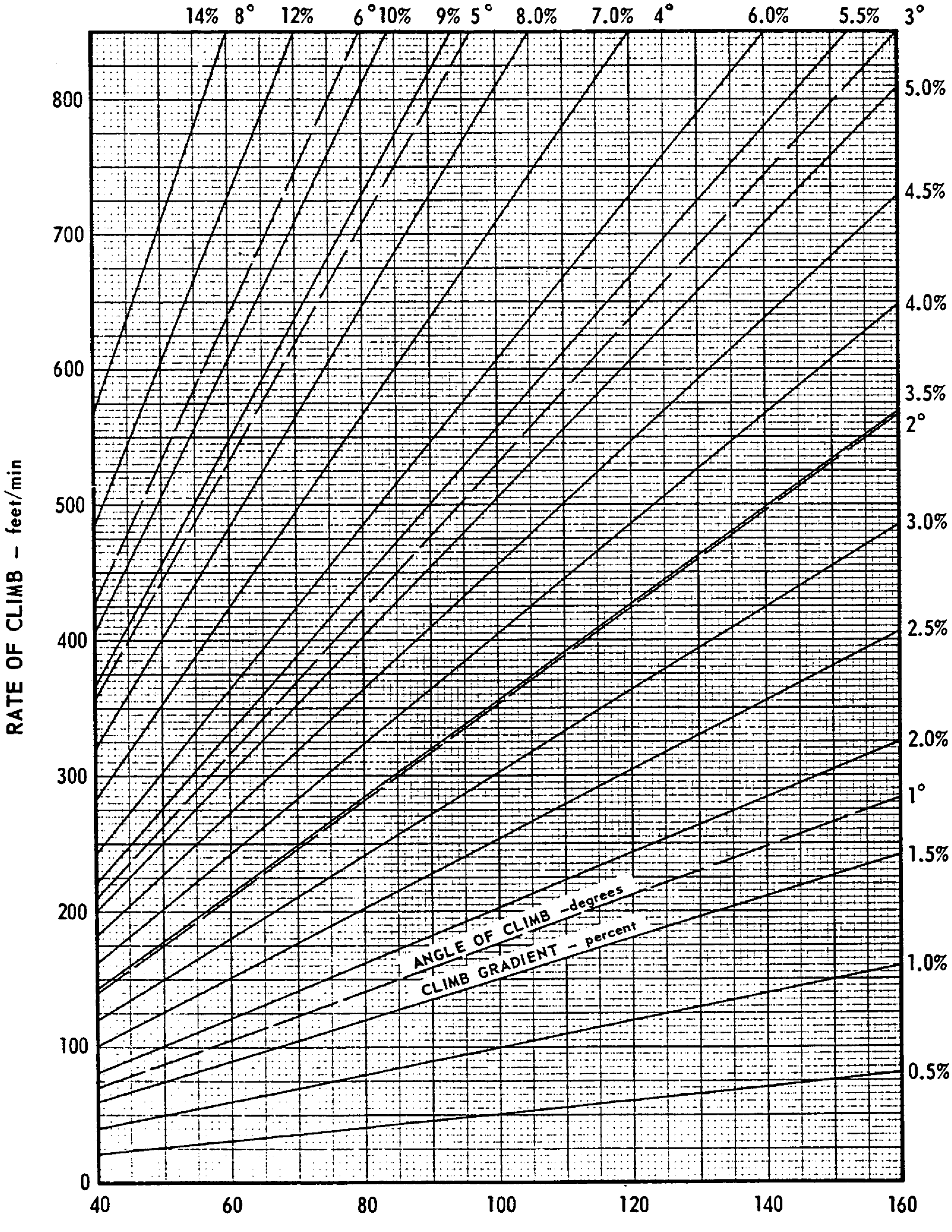
14%
8°
12%
6°
10%
9%
5°
8.0%
7.0%
4°
6.0%
5.5%
3°
5.0%
4.5%
4.0%
3.5%
2°
3.0%
2.5%
2.0%
1°
1.5%
1.0%
0.5%
ANGLE OF CLIMB -degrees
CLIMB GRADIENT - percent
RATE OF CLIMB - feet/min
0
100
200
300
400
500
600
700
800
40
60
80
100
120
140
160
FLIGHT PATH VELOCITY - knots (TAS)

Figure 10

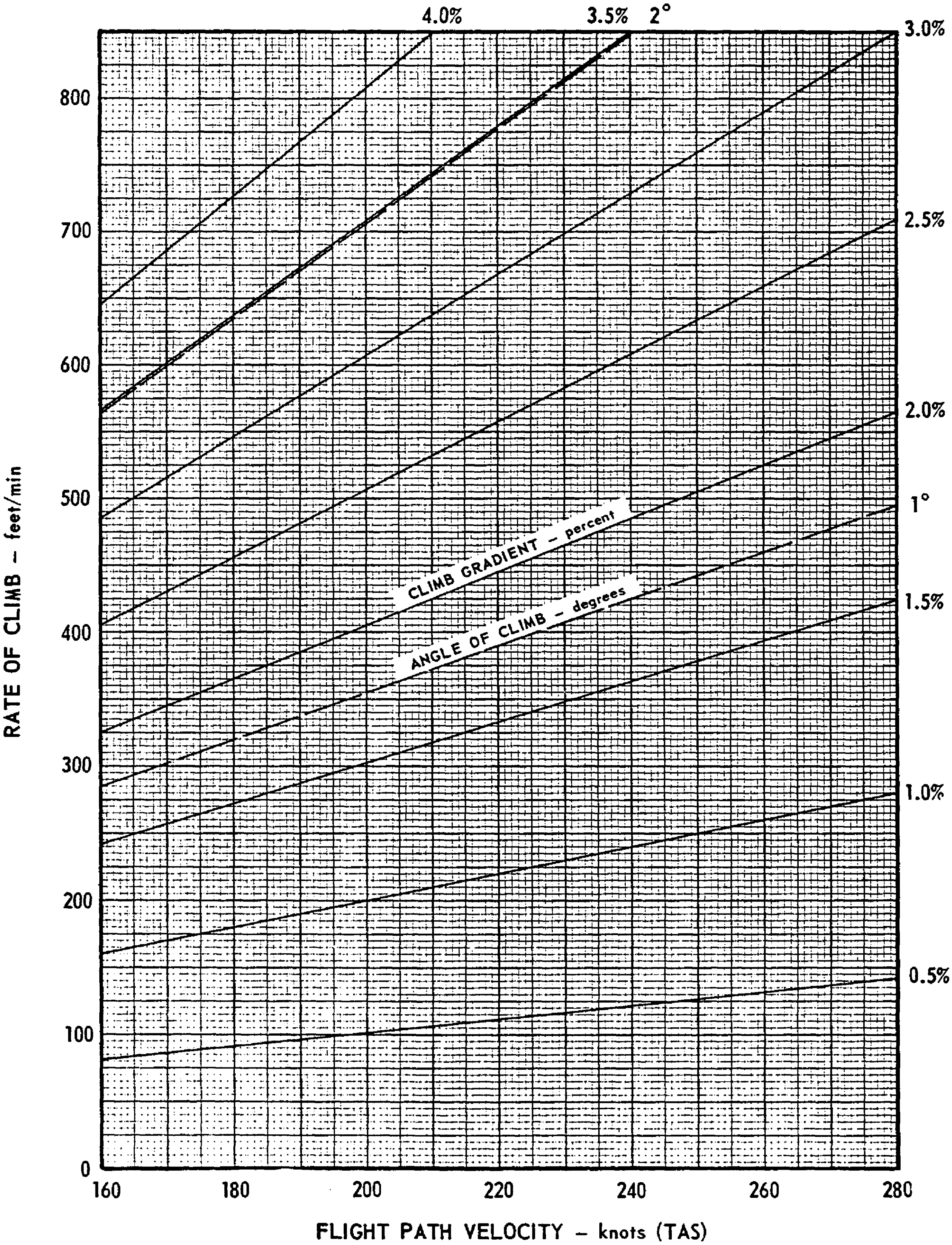

Figure 10 (continued)

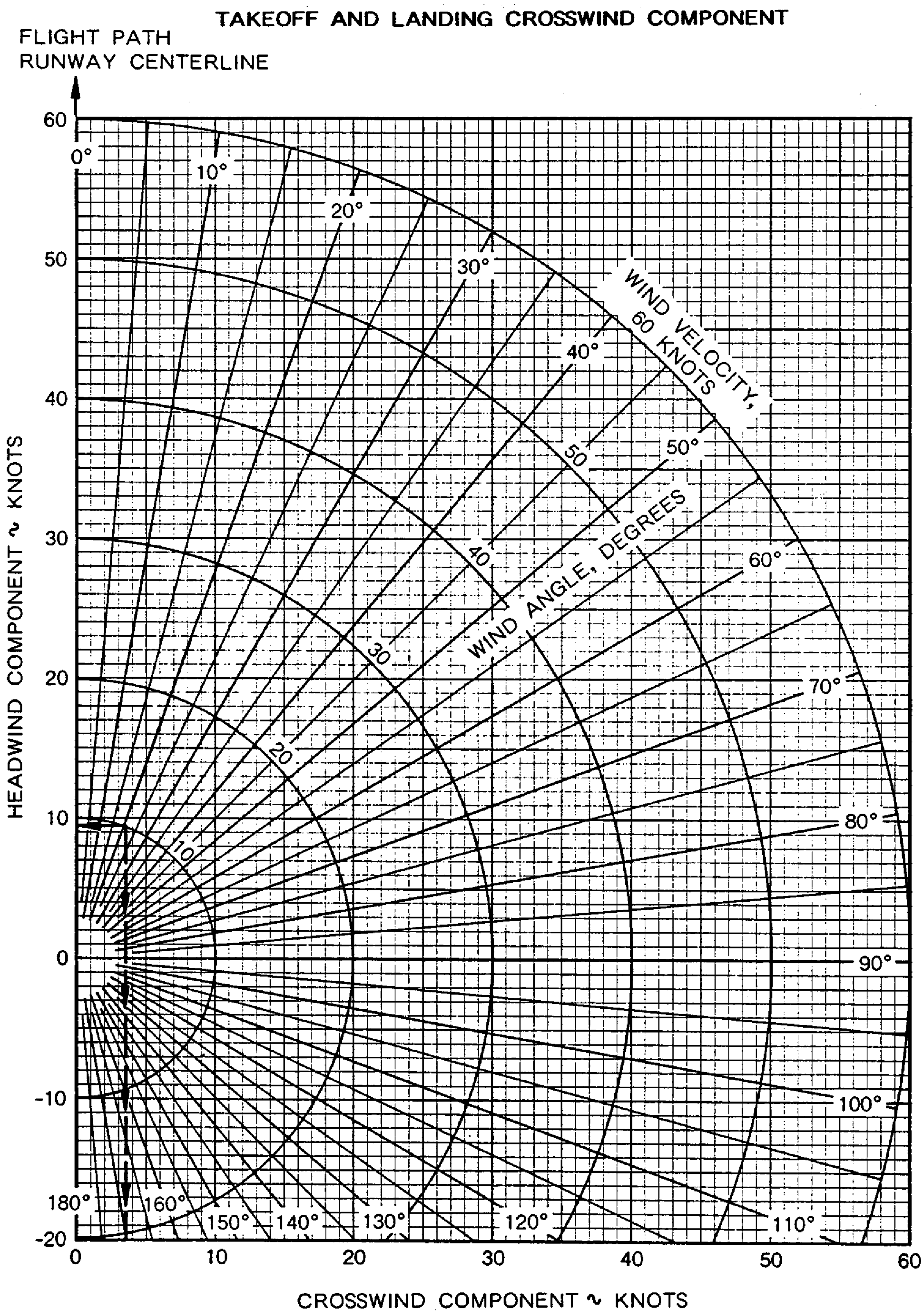
TAKEOFF AND LANDING CROSSWIND COMPONENT
FLIGHT PATH
RUNWAY CENTERLINE
WIND VELOCITY, 60 KNOTS
WIND ANGLE, DEGREES
HEADWIND COMPONENT ∿ KNOTS
CROSSWIND COMPONENT ∿ KNOTS
0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
180°
10
20
30
40
50
60
-10
-20
0

Figure 11

APPENDIX 8. CONVERSION FACTORS TABLE

LENGTH

Multiply	By	To Obtain
Centimeters	0.3937	Inches
	0.03281	Feet
	.01	Meters
Kilometers	3281	Feet
	0.6214	Miles
	0.5399	Nautical Miles
	1093.6	Yards
Meters	39.37	Inches
	3.281	Feet
	1.0936	Yards
Statute Miles	5280	Feet
	0.8690	Nautical Miles
	1760	Yards
Nautical Miles	6076.1	Feet
	1.1508	Statute Miles

WEIGHT

Multiply	By	To Obtain
Grams	0.03527	Ounces (advp)
	0.002205	Pounds (advp)
	1000	Milligrams
	0.001	Kilograms
Kilograms	2.205	Pounds (advp)
	35.27	Ounces (advp)
	1000	Grams
Pounds (advp)	7000	Grains
	16.0	Ounces
	1.215	Pounds (troy)

VOLUME

Multiply	By	To Obtain
Cubic Centimeters	10^{-3}	Liters
	0.0610	Cubic Inches

VOLUME (continued)

Multiply	By	To Obtain
Cubic Feet	28317	Cubic Centimeters
	1728	Cubic Inches
	0.03704	Cubic Yards
	7.4805	Gallons (U.S.)
	28.32	Liters
Cubic Inches	4.329×10^{-3}	Gallons (U.S.)
	0.01732	Quarts (U.S.)
	0.0164	Liters
Cubic Meters	61023	Cubic Inches
	35.31	Cubic Feet
	264.17	Gallons (U.S.)
	1.308	Cubic Yards
Gallons Imperial	277.4	Cubic Inches
	1.201	Gallons (U.S.)
	4.546	Liters
Gallons, U.S.	231	Cubic Inches
	0.1337	Cubic Feet
	3.785	Liters
	0.8327	Imperial Gallons
	128	Fluid Ounces
Fluid Ounces	29.59	Cubic Centimeters
	1.805	Cubic Inches
Liters	61.02	Cubic Inches
	0.2642	Gallons (U.S.)
	1.057	Quarts (U.S.)

AREA

Multiply	By	To Obtain
Square Centimeters	0.1550	Square Inches
	0.001076	Square Feet
Square Feet	144	Square Inches
	0.1111	Square Yards
Square Inches	645.16	Square Millimeters
Square Kilometers	0.3861	Square Statute Miles
Square Meters	10.76	Square Feet
	1.196	Square Yards
Square Statute Miles	2.590	Square Kilometers

VELOCITY

Multiply	By	To Obtain
Feet Per Minute	0.01136	Miles Per Hour
	0.01829	Kilometers Per Hour
	0.5080	Centimeters Per Second
	0.01667	Feet Per Second
Feet Per Second	0.6818	Miles Per Hour
	1.097	Kilometers Per Hour
	30.48	Centimeters Per Second
	0.3048	Meters Per Second
	0.5921	Knots
Knots	1.0	Nautical Miles Per Hour
	1.6878	Feet Per Second
	1.1508	Miles Per Hour
	1.852	Kilometers Per Hour
	0.5148	Meters Per Second
Meters Per Second	3.281	Feet Per Second
	2.237	Miles Per Hour
	3.600	Kilometers Per Hour
Miles Per Hour	1.467	Feet Per Second
	0.4470	Meters Per Second
	1.609	Kilometers Per Hour
	0.8690	Knots
Radians Per Second	57.296	Degrees Per Second
	0.1592	Revolutions Per Second
	9.549	Revolutions Per Minute

PRESSURE

Multiply	By	To Obtain
Atmospheres	29.921	Inches of Mercury
	14.696	Pounds Per Square Inch
	2116.2	Pounds Per Square Foot
Inches of Mercury	0.03342	Atmospheres
	0.4912	Pounds Per Square Inch
	70.727	Pounds Per Square Foot
Inches of Water (at $4^{\circ}C$)	0.00246	Atmospheres
	0.07355	Inches of Mercury
	0.03613	Pounds Per Square Inch
	5.204	Pounds Per Square Foot
Pounds per Square Inch	6.895	Kilo Pascals

POWER

Multiply	By	To Obtain
BTU Per Minute	12.96	Foot Pounds Per Second
	0.02356	Horsepower
Horsepower	33000	Foot Pounds Per Minute
	550	Foot Pounds Per Second
	0.7457	Kilowatts

TEMPERATURE

Degrees Kelvin = Degrees Celsius Plus 273.2
Degrees Rankine = Degrees Fahrenheit Plus 459.7

Multiply	By	To Obtain
Fahrenheit	5/9 (F-32)	Celsius
Celsius	9/5 C+32	Fahrenheit

ANGULAR DISPLACEMENT

Multiply	By	To Obtain
Degrees	1.745×10^{-2}	Radians
Radians	57.3	Degrees

FORCE

Multiply	By	To Obtain
Pounds	4.448	Newtons

APPENDIX 9. AIRSPEED CALIBRATIONS

1. SPEED COURSE METHOD. The speed course method consists of using a ground reference to determine variations between indicated airspeed and ground speed of the airplane. An accurately measured ground course is required. The course distance should be selected to be compatible with the airspeeds being flown. Excessively long times to traverse the course will degrade the test results.

Generally, airspeeds above 250 knots should be flown over a 5-mile course. Below 100 knots, limit the course to 1 mile. Perpendicular "end lines" (roads, powerlines, etc.) should be long enough to allow for drift and accurate sighting of end line passage. One-second error at 200k is 6k on a 2-mile course.

a. Test Conditions.

(1) Air Quality. The air should be as smooth as possible with a minimum of turbulence and wind. The wind velocity, while conducting the test, should not exceed approximately 10 knots.

(2) Weight and C.G. Airspeed calibrations are usually not c.g. sensitive but may be weight sensitive especially at low airspeeds (higher angles of attack). Initial airspeed calibration tests should be conducted with the airplane loaded at or near maximum takeoff gross weight. Additional tests should be conducted at near minimum weight and at low airspeeds to spot check the maximum weight airspeed calibration results. If differences exist, an airspeed system calibration should be accomplished at minimum weight.

(3) Altitude. When using a visual reference on the airplane for timing, the altitude throughout the test run should be as low as practical but should be maintained at least one and one-half wing span above the highest ground elevation so that the airplane remains out of ground effect. When conditions permit using the airplane shadow for timing, speed course altitudes of 500-2000 feet AGL can be used. All run pairs should be conducted at the same altitude.

(4) Speed Range. The speed should range from 1.3 V_{S1} to the maximum level flight speed, to extrapolate to V_D.

(5) Run Direction. Reciprocal runs should be made at each speed to eliminate wind effects and the ground speed obtained in each direction should be averaged to eliminate wind effects. Do not average the time flown in each direction.

(6) Heading. The heading should be maintained constant and parallel to the speed course throughout the run, allowing the airplane to "drift," if necessary, so that the effect of crosswinds can be eliminated.

(7) Configuration. The airspeed system should be calibrated in each landing gear and wing flap configuration required in §§ 23.45 thru 23.77. This normally consists of gear up/flaps up, gear up/flaps takeoff and gear down/flaps down.

b. Test Procedures.

(1) Stabilize airplane in level flight at test speed, with gear and flaps in the desired configuration, prior to entering the speed course.

(2) Maintain constant speed, altitude, and heading through speed course. Record data.

(3) Repeat steps (1) and (2) of this paragraph on the reciprocal speed run.

(4) Repeat steps (1) thru (3) of this paragraph at sufficient increments (minimum of five) to provide an adequate calibration curve for each of the configurations.

c. Data Acquisition and Reduction. Data to be recorded during each run:

(1) Time to make run.

(2) Pressure altitude.

(3) Total air temperature (airplane indicator) corrected to static air temperature (SAT).

(4) Indicated airspeed.

(5) Wing flap position.

(6) Landing gear position.

(7) Direction of run.

d. Sample Speed Course Data reduction (Refer to figure 1).

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

$$1\ \text{Knot} = \frac{6076.1}{3600}\ \frac{\text{feet/nautical mile}}{\text{second/hour}} = 1.6878\ \text{feet/second}$$

$$GS = \frac{10560}{(1.6878)(47.1)} = \frac{.5925\ (10560)}{47.1} = 132.8\ \text{knots}$$

$$GS_{AVE}\ (TAS) = \frac{132.8 + 125.6}{2} = 129.2\ \text{knots}$$

Sample Speed Course Data and Data Reduction

a. Weight ______________ C.G. ______________

b. Course Distance 10,560 Ft.

c. Pressure Altitude 1,600 Ft. (Altimeter set to 29.92")

Flap Position Degrees	Gear Position (Up or Down)	Observed Data: Time Seconds	Observed Data: I.A.S. (Knots)	Observed Data: Pressure Altitude Ft.	Observed Data: SAT. , °F	Ground Speed* Knots	Average Ground Speed, Knots	Factor**	Calibrated Air Speed Knots	Average I.A.S. Knots	Error Knots: Airspeed System	Error Knots: Instrument	Error Knots: Position
	Fixed	47.1	128.0	1610	55	132.8							
0		49.8	129.0	1600	55	125.6	129.2	.975	126.0	128.5	+2.5	+1	+1.5
		44.5	135.0	1600	55	140.5							
		47.1	137.0	1600	55	132.8	136.7	.975	133.3	136.0	+2.7	0	+2.7
		40.5	148.0	1600	55	154.2							
		43.3	148.0	1600	55	144.3	149.3	.975	145.6	148.0	+2.4	-1	+3.4

* Ground Speed $= \dfrac{C \times \text{Course Distance (Ft)}}{\text{Time (Seconds)}}$ C = 0.5925 for course speed in Knots. Or use: C = 0.6818 for M.P.H.

** Factor $= \sqrt{\rho/\rho_o} = 4.16\sqrt{\dfrac{\text{Observed Pressure (In. Hg.)}}{459.7 + \text{Observed Temperature } ^{o}F}}$ (or read from chart)

Figure 1 - SAMPLE SPEED COURSE DATA AND DATA REDUCTION

(1) Density Altitude. TAS is greater than CAS if density altitude is above sea level. For density altitudes below 5000 feet and calibrated airspeeds below 200 knots, it is considered acceptable to use the term CAS = EAS = TAS$\sqrt{\rho/\rho_o}$. In this case, density altitude is obtained from figure 4 in appendix 7. At 1600' pressure altitude and SAT 55°F, we read a density altitude of about 1700 feet. This density altitude intercepts $\sqrt{\rho/\rho_o}$ at a value of .975. CAS = 129.2 (0.975) = 126.0 knots.

AVERAGE GS (TAS)	CAS	IAS	ERROR System =	Instrument +	Position
129.2	126.0	128.5	+2.5	+1	+1.5
			(CAS-IAS)	Vinst	Vpos

(2) Required Accuracy. Instrument error is determined by applying standard pitot and static pressures to the airspeed instrument and developing a calibration curve. IAS corrected for +1 instrument error = 127.5 knots. The position of the static source is causing +1.5 error. Section 23.1323(b) requires the system error, including position error, but excluding instrument error, not to exceed 3% of CAS or 5 knots whichever is greater, in the designated speed range.

(3) Compressibility. For many years CAS was used for design airspeeds. However, as speeds and altitudes increased, a compressibility correction became necessary because airflow produces a total pressure on the pitot head which is greater than if the flow were incompressible. We now use EAS as a basis for design airspeeds (§ 23.235). Values of CAS vs. EAS may be calculated or you may use the chart in appendix 7, figure 5, to convert knots CAS to EAS.

2. TRAILING BOMB AND/OR AIRSPEED BOOM METHOD.

a. Test Conditions.

(1) Air Quality. Smooth, stable air is needed for calibrating the airspeed indicating system using a trailing bomb or airspeed boom.

(2) Weight and C.G. Same as speed course method. See paragraph 1a(2) of this appendix.

(3) Speed Range. The calibration should range from just above stall to V_{MO}/V_{NE} or maximum level flight speed whichever is greater. If the trailing bomb becomes unstable at high airspeed, the higher airspeed range may be calibrated using another accepted method; that is, trailing cone or speed course.

(4) Use of Bomb. Care should be exercised in deploying the bomb and flying the test to ensure that no structural damage or control interference is caused by the bomb or the cable. At higher speeds, the bomb may become unstable and porpoise or oscillate. A means for a quick release of the trailing bomb should be provided, in the event an emergency arises. Flight tests using a bomb should be conducted over open (unpopulated) areas.

(5) Free Stream Air. The bomb hose should be of adequate length to assure bomb operations in free stream air. This should include consideration of all airplane test configurations which could possibly impart body interference upon the bomb. It will usually require that the bomb be at least one-half wing span away from the airplane.

(6) Qualifications For Use. Under stabilized flight conditions at constant airspeed and altitude, trailing cones and airspeed bombs are considered excellent airspeed reference systems. See paragraph 17b of this AC for additional discussion.

b. Test Procedures.

(1) Stabilize airplane in level flight approximately 30 seconds just above stall with flaps and gear retracted. Record data.

(2) Repeat step (1) at sufficient increments to provide an adequate calibration curve for each of the configurations.

c. Data Acquisition and Reduction. Data to be recorded at each test point:

(1) Airplane IAS.

(2) Bomb or boom IAS.

(3) Wing flap position.

(4) Landing gear position.

(5) Attitude (level or descent).

See figure 2 for sample calculations using the trailing bomb.

3. PACE AIRPLANE METHOD.

a. Test Conditions.

(1) Test conditions are the same as those required for the trailing bomb calibration with the exception of those conditions specifically applicable to use of the trailing bomb.

(2) Assurance should be obtained that the pace airplane has been accurately calibrated. The calibration should have been accomplished recently and the calibration curve available.

b. Test Procedures. The test procedures are the same as those for calibration using the trailing bomb. The pace airplane is flown at the same altitude as the test airplane and a relative velocity of zero maintained between the two at each test airspeed. The pace airplane must be close to ensure that pace and test airspeeds are the same, but far enough away so that the pressure fields of the two airplanes do not interact. Readings are coordinated by radio.

Sample Test Data

Flap Position (Degrees)	Gear Position (Up or Down)	OBSERVED DATA			Bomb Correction (knots)	Calibrated Airspeed (knots)	ERROR (knots)		
		Airplane I.A.S. (knots)	Bomb I. A. S. (knots)	Flight Attitude (Level or Diving)			Airspeed System	Instrument	Position
0	Fixed	50	63.2	Level	+0.3	63.5	-13.5	-3	-10.5
		60	67.2	"	+0.2	67.4	-7.4	-2	-5.4
		70	74.2	"	+0.2	74.4	-4.4	-2	-2.4
		80	82.5	"	+0.3	82.8	-2.8	-1	-1.8
		90	91.5	"	+0.3	91.8	-1.8	0	-1.8
		100	100.5	"	+0.4	100.9	-0.9	0	-0.9
		110	108.8	"	+0.4	109.2	0.8	1	-0.2
		120	118.2	"	+0.7	118.9	1.1	2	-0.9
		130	128.0	"	+0.7	128.7	1.3	2.5	-1.2
		140	137.5	"	+0.7	138.2	1.8	3	-1.2

Sample Calculations:

CAS = Bomb IAS + Bomb Correction
= 63.2 + 0.3 = 63.5 knots

System error = IAS - CAS
= 50 - 63.5 = -13.5 knots

System error = position error + instrument error

-13.5 = position error + (-3)
-13.5 - (-3) = position error
-10.5 = position error

Figure 2 - BOMB AIRSPEED DATA REDUCTION

c. Data to be recorded:

(1) Test airplane, IAS (knots).

(2) Test airplane pressure altitude.

(3) Pace airplane, IAS (knots).

(4) Pace airplane pressure altitude.

d. Data Reduction. The data reduction process is the same as that used for reducing data from a trailing bomb calibration.

4. GROUND RUN AIRSPEED SYSTEM CALIBRATION. The airspeed system is calibrated to show compliance with commuter category requirements of § 23.1323(c) during the accelerate-takeoff ground run, and is used to determine IAS values for various V_1 and V_R speeds. The airspeed system error during the accelerate-takeoff ground run may be determined using a trapped static source reference, or a distance measuring unit which provides readouts of ground speed which can be converted into CAS.

a. Definitions.

(1) Ground Run System Error. System error during the accelerate-takeoff ground run is the combination of position error, instrument error, and the dynamic effects, such as lag, which may be caused by acceleration on the runway.

(2) Trapped Static Source. An airtight bottle with sufficient internal volume so as to be infinite when compared to an airspeed indicator's internal changes in volume while sensing various airspeeds. The bottle should be insulated to minimize internal bottle temperature changes as testing is in progress. For short periods of time, it can be assumed that the bottle will reflect true static ambient pressure to the test indicator.

(3) Production Airspeed Indicator. An airspeed indicator which conforms to the type certification design standards. The indicator should be installed in the approved instrument panel location since these tests involve the dynamic effects of the indicator which may result from acceleration.

(4) Test Airspeed Indicator. A mechanical airspeed indicator with known dynamic characteristics during acceleration or an electronic transducer which can provide airspeed information.

(5) Test Reference Altimeter. An altimeter which indicates the altitude of the air trapped in the bottle or local ambient static air if the valve is opened.

(6) Ground Run Position Error. Ground run position error is the static-pressure error of the production static source during ground runs with any ground effects included. Any contributions to error due to the total-pressure (pitot) are ignored.

(7) Instrument Error. See paragraph 302a(3)(ii).

(8) Dynamic Effects on Airspeed Indicator. The dynamic effects on airspeed indicators occur as a result of acceleration and rapid change in airspeed during takeoff. This causes many airspeed indicators to indicate an airspeed lower than the actual airspeed.

NOTE: It is possible for electronic airspeed indicators driven by an air data computer to also have errors due to dynamic acceleration effects because of characteristics inherent in the basic design.

(9) Distance Measuring Unit. An instrumentation system normally used to record takeoff distance measurements. One output of these systems provides the ground speed vs. time as the airplane accelerates during the accelerate-takeoff ground run. Ground speed may be converted into a corresponding CAS value by applying wind and air density corrections at intervals during acceleration where the ship's airspeed indications have been recorded.

b. Trapped Static Source Method. The trapped static source method consists of comparing instantaneous readings of airspeed, as indicated on a test airspeed indicator, with readings on a production airspeed indicator while accelerating on the runway. The two airspeed indicators should be located in close proximity to each other. Readings may be recorded by film or video cameras for mechanical airspeed indicators or by electronic means if a transducer type device is being utilized. See figure 3 for system schematic.

(1) Test Conditions.

(i) Air Quality. The surface winds should be light with a minimum of gusting.

(ii) Weight and C.G. Ground run calibrations are not sensitive to C.G. The dynamic effects of acceleration may be affected by weight. Test weight variations should be sufficient to account for any measurable effects due to weight.

(iii) Speed Range. The speeds should range from .8 of the minimum V_1 to 1.2 times the maximum V_1, unless higher values up to V_R are required for expansion of takeoff data.

(iv) Configuration. The airspeed system should be calibrated during the accelerate-takeoff ground run for each approved takeoff flap setting.

(2) Test Procedures.

(i) Align the airplane with the runway.

(ii) With idle engine power and with the cabin door open, open the valve to expose the bottle to static ambient conditions, then close the valve. Record the test altimeter reading.

(iii) Close the cabin door.

(iv) Conduct a takeoff acceleration using normal takeoff procedures. The camera should be recording speeds from the two airspeed indicators in increments sufficient to cover the required airspeed range.

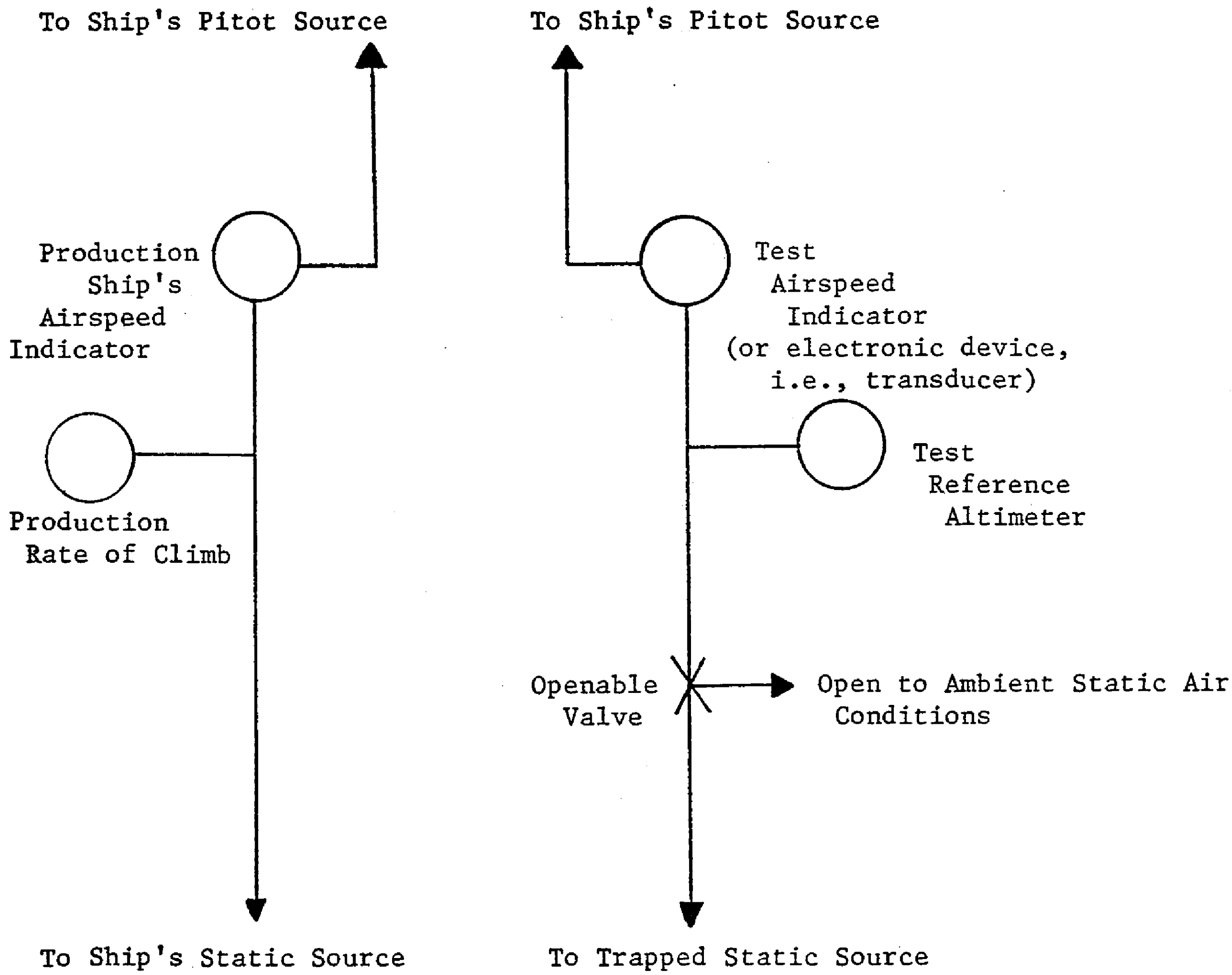

Figure 3 - TRAPPED STATIC SOURCE SCHEMATIC

(v) The takeoff run should be continued, if possible, until beyond the maximum required speed then aborted. When at rest with engines idling, open valve again and observe the test altimeter. Any significant jumps or changes in indicated altitude may indicate a system leak, too much runway gradient or other factors which will invalidate the results of the run.

(vi) Repeat steps (i) thru (v) of this paragraph until there are sufficient runs to provide adequate calibration curves for the required configurations.

(3) Data Acquisition and Reduction. Read the recorded data (film or video) at increments of airspeed arbitrarily selected within the required range. See figure 4 for a sample data reduction. Record and perform the following:

TIME	TRAPPED STATIC (TS) IAS (KNOTS)	(1) TS AIRSPEED INSTRUMENT CORRECTION	CORRECTED TS IAS	SHIP'S IAS (KNOTS)	(1) SHIP'S AIRSPEED INSTRUMENT CORRECTION	CORRECTED SHIP'S IAS	(2) AIRSPEED ERROR
7:41:45	50.7	0	50.7	49	0	49	1.7
:46	56.1		56.1	54		54	-2.1
:47	61.4		61.4	61		61	-0.4
:48	66.9		66.9	66		66	-0.9
:49	71.9		71.9	72		72	0.1
:50	76.7		76.7	77		77	0.3
:51	82.1		82.1	83		83	0.9
:52	86.8		86.8	88		88	1.2
:53	91.5		91.5	91		91	-0.5
:54	96.5		96.5	99		99	2.5
:55	100.9		100.9	102		102	1.1
:56	105.2		105.2	107		107	1.8
:57	110.1		110.1	113		113	2.9
:58	114.4		114.4	119		119	4.6
:59	118.2		118.2	123		123	4.8
7:42:00	122.9		122.9	128		128	5.1

NOTES:
1. Obtain from instrument calibration
2. Corrected ship's IAS minus corrected trapped static IAS

Figure 4 - TRAPPED STATIC DATA REDUCTION

(i) Production indicated airspeed, test indicated airspeed, and configuration.

(ii) Correct the test indicated airspeed for instrument error and in the case of electronic devices, any known dynamic effects. Static pressure in the bottle is assumed to result in no position error. These corrected airspeed values may be assumed to be CAS.

(iii) Calculate the amount of system error (difference between corrected test indicated airspeed and production indicated airspeed). It may be appropriate to correct for differences in the ship's airspeed error between the test instrument and the average error identified in design specifications of like production indicators.

(iv) Plot IAS vs. CAS within the required range of speeds. See figure 5 for a sample plot.

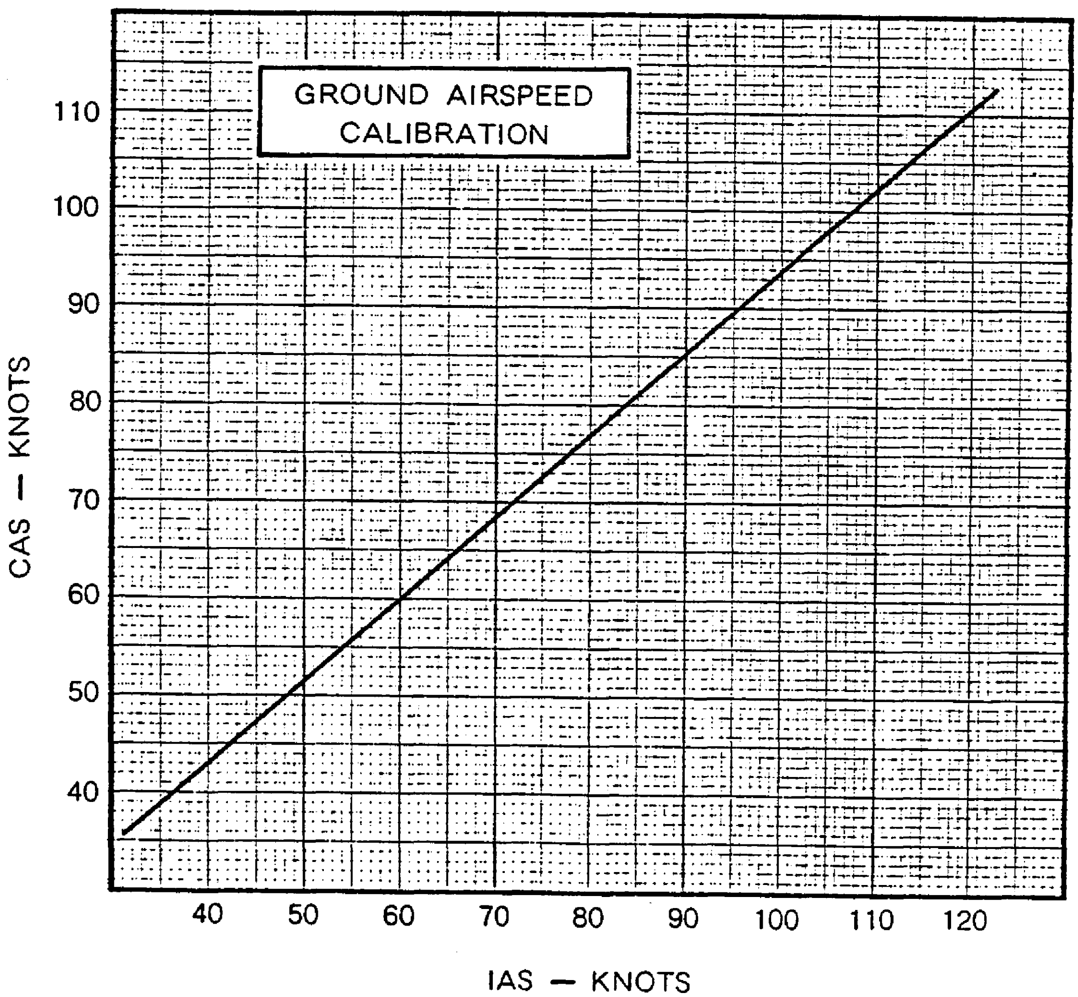

Figure 5 - GROUND AIRSPEED CALIBRATION

c. Distance Measuring Unit Method. The distance measuring unit method consists of utilizing the readouts of ground speed to obtain CAS values within the required range of speeds. These values are compared with readings at the same instant on a production airspeed indicator. Airspeed indicator readings may be recorded by film or video cameras for mechanical airspeed indicators or by electronic means if a transducer type device is being utilized. There should be a method of correlating recorded airspeeds with the CAS values obtained from the distance measuring unit system.

(1) Test Conditions.

(i) Air Quality. The surface wind velocity should be steady, as low as possible, and not exceed 10 knots. The wind direction should be as near as possible to the runway heading.

(ii) Weight and C.G. Same as for the trapped static source method.

(iii) Speed Range. Same as for the trapped static source method.

(iv) Configuration. Same as for the trapped static source method.

(2) Test Procedures.

(i) Align the airplane with the runway.

(ii) Conduct a takeoff acceleration using normal takeoff procedures. The distance measuring unit should be recording/determining the ground speeds. The camera should be recording speeds from the production airspeed indicator and the time or counting device utilized to correlate speeds.

(iii) The takeoff may continue or be aborted when beyond the maximum required speed.

(iv) Record surface wind velocity and direction; surface air temperature and runway pressure altitude for each run.

(v) Repeat steps (i) thru (iv) of this paragraph until there are sufficient runs to provide adequate calibration curves for the required configurations.

(3) Data Acquisition and Reduction. Read the recorded data (film or video) at increments of airspeed arbitrarily selected within the required range. For these same increments, determine the ground speeds from the distance measuring unit system. See figure 6 for a sample data reduction. Record and perform the following:

TIME	DMU GROUND SPEED (KNOTS)	WIND COMPONENT DOWN THE RUNWAY	TAS (KNOTS)	(1) CAS (KNOTS)	SHIP'S IAS (KNOTS)	(2) SHIP'S AIRSPEED INSTRUMENT CORRECTION	CORRECTED SHIP'S IAS	(3) GROUND AIRSPEED ERROR
07:00:09	48.0	3	51.0	50.1	49	0	49	-1.1
:10	52.8		55.8	54.8	54		54	-0.8
:11	56.8		59.8	58.7	59		59	+0.3
:12	61.0		64.0	62.8	63		63	+0.2
:13	64.2		67.2	66.0	68		68	+2.0
:14	67.3		70.3	69.0	71		71	+2.0
:15	70.9		73.9	72.5	75		75	+2.5
:16	74.0		77.0	75.6	78		78	+2.4
:17	77.2		80.2	78.7	82		82	+3.3
:18	80.7		83.7	82.2	83		83	+0.8
:19	83.9		86.9	85.3	87		87	+1.7
:20	87.0		90.0	88.3	89		89	+0.7
:21	90.6		93.6	91.9	92		92	+0.1
:22	93.8		96.8	95.1	95		95	-0.1
:23	96.9		99.9	98.1	101		101	+2.9
:24	100.3		103.3	101.4	103		103	+1.6
:25	103.6		106.6	104.7	106		106	+1.3
:26	106.6		109.6	107.6	110		110	+2.4

Test Conditions:
- Pressure Altitude - 1240 ft.
- Temperature - $52^{o}F$
- $\sqrt{\sigma}$ - 0.982
- Runway 1
- Wind 350/3

NOTES:
1. $CAS = TAS(\sqrt{\sigma})$
2. Obtain from instrument calibration
3. Corrected Ship's IAS minus CAS

Figure 6 - SAMPLE GROUND AIRSPEED CALIBRATION USING A DISTANCE MEASURING UNIT

(i) Production indicated airspeed, ground speed, surface air temperature, runway pressure altitude, wind velocity and wind direction with respect to runway heading.

(ii) Compute a CAS value for each data point. This is accomplished by identifying the wind component parallel to the runway; computing the corresponding true airspeed; computing the air density ratio; then computing the calibrated airspeed.

(iii) Calculate the amount of system error (difference between CAS and production indicated airspeed).

(iv) Plot IAS vs. CAS within the required range of speeds. See figure 5 for a sample plot.